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ARRANGEMENT AND METHOD FOR ITERATIVE CHANNEL IMPULSE RESPONSE ESTIMATION

Field of the Invention

This invention relates to systems employing transmission channels, and particularly (though not exclusively) to wireless cellular telecommunication systems.

Background of the Invention

In the field of this invention it is known that the receiver performance in wireless cellular telecommunication systems relies on the estimate of the impulse response of the overall channel which includes the transmitter pulse, the radio channel, and the receiver selectivity filtering.

From the publication "Iterative channel estimation using soft decision feedback", by Magnus Sandell et al., Global Telecommunications Conference, 1998. GLOBECOM 1998. The Bridge to Global Integration. IEEE, Volume: 6, 1998, pp. 3728 -3733, iterative channel impulse response estimation is known using soft decision feedback. In this known technique, channel impulse response estimation is improved through an iterative process which increases the number of known symbols in a received modulated signal by iteratively feeding back successive tentative decisions from an equaliser to a channel impulse response estimator.

However, this approach has the disadvantage that a great part of the complexity of the technique depends on the complexity of the equalizer, which may dramatically increase with the number of points in the modulation constellation.

A need therefore exists for iterative channel impulse response estimation using noise estimate wherein the abovementioned disadvantage may be alleviated.

Patent specification WO 01/61950 describes a method channel impulse response estimation using whitening filters in the noise estimate. In this method, a plurality of channel impulse response and noise sample estimates are needed for each iteration and the whitening filters introduce delay and added complexity.

Statement of Invention

The present invention provides an arrangement and a method for iterative channel impulse response estimation as described in the accompanying claims.

Brief Description of the Drawings

One arrangement and method for iterative channel impulse response estimation using noise estimate incorporating the present invention will now be described, by way of

example only, with reference to the accompanying drawings, in which:

FIG. 1 shows a prior art arrangement for iterative channel impulse response estimation; and

FIG. 2 shows a prior art receiver arrangement for iterative channel impulse response estimation; and

FIG. 3 shows a receiver arrangement for iterative channel impulse response estimation incorporating the present invention.

Description of Preferred Embodiment

FIG. 1 shows, in outline, a GSM/EDGE ("Groupe Spéciale Mobile" or General System for Mobile communications/Enhanced Data rates for GSM Evolution) wireless cellular telephone communication system 10 in which the present invention may be used.

Generally, the system's air-interface protocol is administered from base transceiver sites that are geographically spaced apart - one base site supporting a cell (or, for example, sectors of a cell).

A plurality of subscriber units (MSs) 12-16 communicate over the selected air-interface 18-20 with a plurality of base transceiver stations (BTSs) 22-32. A limited number of MSs 12-16 and BTSs 22-32 are shown for clarity purposes only. The BTSs 22-32 may be connected to a

conventional public-switched telephone network (PSTN) 34 through base station controllers (BSCs) 36-40 and mobile switching centres (MSCs) 42-44.

Each BTS 22-32 is principally designed to serve its primary cell, with each BTS 22-32 containing one or more transceiver units and communicating 56-66 with the rest of the cellular system infrastructure

Each Base Station Controller (BSC) 36-40 may control one or more BTSs 22-32, with BSCs 36-40 generally interconnected through MSCs 42-44.

Each MSC 42-44 provides a gateway to the PSTN 34, with MSCs 42-44 interconnected through an operations and management centre (OMC) 46 that administers general control of the cellular telephone communication system 10, as will be understood by those skilled in the art.

The various system elements, such as BSCs 36-38 and OMC 46, will include control logic 48, 50, 52, with the various system elements usually having an associated memory function 54 (shown only in relation to BSC 38 for the sake of clarity). The memory function 54 typically stores historically compiled operational data as well as in-call data, system information and control algorithms.

In each MS, receiver performance relies on an estimate of the impulse response of the overall channel which includes the transmitter pulse, the radio channel, and the receiver selectivity filtering.

Assuming the use of linear or quasi-linear modulations, the complex base band received signal may be represented as:

$$y(t) = \sum_k a_k \cdot p(t - k \cdot T) + b(t)$$

where $\{a_k\}$ is the original transmitted symbol sequence, $p(t)$ represents the complex impulse response of the overall channel and $b(t)$ is the unwanted signal, called noise (filtered Gaussian noise, interferers such as upper adjacent interferer, lower adjacent interferer, co-channel interferer, etc.).

The Weighted Least Square algorithm provides for an estimate $\hat{p}(t)$ of $p(t)$ which minimizes the mean squared distance between $\hat{p}(t)$ and $p(t)$. Working with sampled signals, the generic equation is:

$$\underline{\hat{p}} = (H^H \cdot W \cdot H)^{-1} \cdot H^H \cdot W \cdot \underline{y}$$

where:

$\underline{\hat{p}}$ is the vector of L_p estimated samples of the overall channel.

$\underline{y}$ is the vector of L_y received samples corresponding to the sequence of known symbols.

H is a $\lfloor L_y, L_p \rfloor$ matrix depending on known symbols

W is a $\lfloor L_y, L_y \rfloor$ weighting matrix representing the inverse of the noise covariance.

There is no *a priori* knowledge on the statistical properties of the noise which evolves according to the position of a mobile station within a cell, according to the number of users, and according to the frequency

channel in case of frequency hopping. In most of existing implementations, W is constant to the benefit of a specific noise (filtered Gaussian noise for instance) or of less complexity when W is equal to the identity matrix (white Gaussian noise).

Referring now to FIG. 2, a known arrangement 200 for deriving a channel impulse response estimate in a receiver such as MSs 12-16 uses a channel impulse response estimator 210 and an equalizer 220. A received signal is applied to both the equalizer and to the channel impulse response estimator, which is initially trained with a predetermined training sequence. The channel impulse response estimator 210 produces an estimated channel signal which is applied to the equalizer 220, where it is used to produce a tentative decision for modulated symbols in the received signal. The tentative decisions are iteratively fed back to the channel impulse response estimator 210, to modify estimated channel signal so as to improve the tentative symbol decisions.

However, this known approach has the disadvantage that a great part of the complexity of the technique depends on the complexity of the equalizer 220, which may dramatically increase with the number of points in the modulation constellation.

Referring now to FIG. 3, an arrangement 300 for improving the quality of the overall channel impulse response estimate for use in a receiver such as MSs 12-16 includes a channel impulse response estimator 310 (known per se)

and a noise estimator 320 (whose function will be described in more detail below). A received signal is applied to both the channel impulse response estimator 310 and to the noise estimator 320; both the channel impulse response estimator 310 and the noise estimator 320 are initially trained with a predetermined training sequence. The channel impulse response estimator 310 produces an estimated channel signal which is applied to the noise estimator 320 and to a further stages such as an equalizer (not shown) where it is used to produce decisions for modulated symbols in the received signal. The noise estimator 320 produces parameters depending on noise in the received signal; these parameters are applied to further stages (not shown) and are also fed back to the channel impulse response estimator 310, to modify the estimated channel signal so as to improve symbol decisions.

In this technique, channel impulse response estimation is done by iterations. Each iteration provides updated knowledge about statistical properties of the noise and updated channel impulse response estimate. A first estimate of the channel is fed to the noise estimator 320 which estimates the noise parameters which are then provided to the channel impulse response estimator which estimates the channel and so on.
The sequence of operations of the method is detailed below:

Initialisation

The first estimate of the channel impulse response $\underline{p(0)}$ can be computed by using an *a priori* weighting matrix or by using a correlation method which is widely used for GSM training sequences

Iteration K *for* $K>0$

The vector of noise samples $\underline{b(K)}$ is given by:

$$\underline{b(K)} = \underline{y} - H \cdot \underline{p(K-1)}$$

Then $\underline{r(K)}$, the vector of L_r noise covariance taps, is computed from the estimated noise samples:

$$\underline{r(K)} = win_k \cdot \sum_{l=k}^{L_y-1} b_l(K) \cdot b_{l-k}(K)^*$$

where win_k is a windowing function with a positive Fourier transform.

Then the new channel impulse response estimate is given by:

$$\underline{p(K)} = (H^H \cdot W(K) \cdot H)^{-1} \cdot H^H \cdot W(K) \cdot \underline{y}$$

where $W(K)$ is the new weighting matrix.

For the computation of equation members including $W(K)$, two modes of computation are possible:

- mode A: on the fly.
- mode B: precomputed values which correspond to the statistics of the expected noises (e.g., Gaussian noise, upper adjacent interferer noise, lower adjacent interferer noise, or co-channel interferer noise).

In mode A, the $\lfloor L_y, L_y \rfloor$ matrix $W(K)$ is given by :

$$W(K) = \begin{bmatrix} r_0(K) & r_1(K) & \cdots & r_{L_r-1}(K) & 0 & \cdots & 0 \\ r_1(K)^* & r_0(K) & \cdots & r_{L_r-2}(K) & r_{L_r-1}(K) & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{L_r-1}(K)^* & r_{L_r-2}(K)^* & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & r_{L_r-1}(K)^* & r_{L_r-2}(K)^* & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & r_1(K) \\ 0 & 0 & 0 & \cdots & \cdots & r_1(K)^* & r_0(K) \end{bmatrix}^{-1}$$

In mode B, the vector $\underline{r(K)}$ is compared with a set of N_r expected vectors $\underline{r^M}$ and the $\lfloor L_y, L_y \rfloor$ matrix $W(K)$ is given by:

$$W(K) = W^{M_{opt}} = \begin{bmatrix} r_0^{M_{opt}} & r_1^{M_{opt}} & \cdots & r_{L_r-1}^{M_{opt}} & 0 & \cdots & 0 \\ r_1^{M_{opt}}{}^* & r_0^{M_{opt}} & \cdots & r_{L_r-2}^{M_{opt}} & r_{L_r-1}^{M_{opt}} & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{L_r-1}^{M_{opt}}{}^* & r_{L_r-2}^{M_{opt}}{}^* & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & r_{L_r-1}^{M_{opt}}{}^* & r_{L_r-2}^{M_{opt}}{}^* & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & r_1^{M_{opt}} \\ 0 & 0 & 0 & \cdots & \cdots & r_1^{M_{opt}}{}^* & r_0^{M_{opt}} \end{bmatrix}^{-1}$$

where M_{opt} is the index of the vector which minimizes the distance between $\underline{r(K)}$ and $\underline{r^M}$.

It will be understood that the technique for iterative channel impulse response estimation using noise estimate described above provides the following advantages:

- Less complexity;
- Independence of the particular equalization method; and

- Consequent performance improvement (tests have shown that use of this technique in a EDGE system can result in a performance improvement of 1.8dB).

It will be understood that, if desired, the technique for iterative channel impulse response estimation using noise estimate described above could be with the prior art technique of FIG. 2.

It will also be understood that, although the technique for iterative channel impulse response estimation using noise estimate has been described above in relation to the receiver in a mobile station (MS), the technique could also be applied to the receiver in a base station (BTS).

It will be appreciated that the method described above for iterative channel impulse response estimation using noise estimate will typically be carried out in software running on a processor (not shown), and that the software may be provided as a computer program element carried on any suitable data carrier (also not shown) such as a magnetic or optical computer disc.

It will also be appreciated that various modifications to the embodiment described above will be apparent to a person of ordinary skill in the art.